

## Automation Interface Design Development

Completed Technology Project (2006 - 2010)



## Project Introduction

The addition of automation has greatly extended humans' capability to accomplish tasks, including difficult, complex, and safety critical tasks. The majority of Human - Automation Interaction (HAI) results in more efficient and safe operations; however, certain unexpected automation behaviours, or "automation surprises" can be frustrating and, in certain safety critical operations (e.g., transportation, spaceflight, medicine), may result in injuries or the loss of life. (Mellor, 1994; Leveson, 1995; FAA, 1995; BASI, 1998; Shaylor, 2000; Sheridan, 2002).

The next generation of space exploration systems will place an increased reliance on automation. Traditional techniques for the design and evaluation of automation interfaces rely on subject-matter-experts, human-in-the-loop testing (i.e., usability testing), guidelines, heuristics, and rules-of-thumb. Given the volume and time-line for the development of new automation required for space exploration, the time and cost required to perform these evaluations by human factor experts will be prohibitive. Further, guidelines, heuristics, and rule-of-thumb have previously yielded sub-optimum designs (as they are focused on the interface, not on the process of interaction between human and automation interface). State of the art cognitive science and Human-Automation Interaction (HAI) approaches may provide the type of analysis needed, but are not currently usable by designers without extensive cognitive science expertise.

The automation design community needs methods that are usable by designers early in the design process to meet the demands for the development and testing of automation required for space exploration. The objective of this research project is to develop a set of methodologies and tools to support the design and evaluation efficient, and robust interaction with automation. The research plan is to integrate existing foundational research results into HAI methods and tools usable by designers. This work is divided into three areas, with the ultimate goal of developing a suite of tools to support each area. It is important to note that the idea of the project is to develop and evaluate the tools in actual design processes, and the level and type of support and evaluation will be dependent upon the scope and maturity of each design domain. The three areas are organized around an abstraction of the primary foci of the design process.

**Analyze:** The first set of methods and tools are intended to help designers to identify, describe, and evaluate the different parts of the job. Depending on the stage of the design process, these methods are referred to as work domain analyses, task decompositions, task analyses, knowledge elicitation, and in the later stages, validation.

**Formulate:** The second set of methods and tools is intended to bridge the gap from the analysis of the work domain. Specifically, once the structure of the work domain and tasks has been determined, methods and tools are needed



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to link the task structures to corresponding interface structures that can later be refined and evaluated. We will be drawing upon research from a number of different communities for this effort including ecological interface design and design patterns.

**Build:** This set of methods and tools are intended to enable rapid development and evaluation of automation, including the user-interface and the underlying automation behavior. The specific focus of this effort is to develop methods and tools that are usable by designers who are expert in the design domain, but aren't necessarily formally trained in computer programming, or human performance analysis. We will primarily be using research in formal methods to help support the Build effort.

The outcomes of this research will be methods and tools for the automation of the design and evaluation of the automation interfaces. These tools will provide the means to: (i) meet the demand for analysis required for space exploration development time-line, (ii) enable increased iterative human factors testing of automation prototypes early in the design process, (ii) reduce the cost of development by design and testing of proposed systems early in the development life-cycle, (iii) reduce the cost of training and the maintenance of proficiency, (iv) improve safety (and reduce the costs of inefficiency and unsafe operations) through significant reduction in failure to complete task metrics.

The 2010 AITD (Automation Interface Design Development) efforts can be summarized in terms of the three efforts: To continue the Analyze method and tool development, the team will identify and analyze a new application domain. To develop and evaluate the Formulate methods and tools, the team will conduct a study to evaluate performance of a modified Scheduling and Planning System for Exploration (SPIFe) interface that will be made comparable to the existing interface (e.g., the graphical elements will be made similar for both interfaces) to examine the evaluation of task to interface structure. If funding allows, the group will also help develop a new version of the SPIFe tool which incorporates the functionality needed for the Attitude Determination and Control Officers (ADCO) planning tasks.

### Anticipated Benefits

Methods and tools for improving the design of automation that were developed for NASA can also be applied to design of interaction between humans and automation/computers in other, commercial, or government applications, particularly in safety-critical work domains.

### Organizational Responsibility

**Responsible Mission Directorate:**

Space Operations Mission Directorate (SOMD)

**Lead Center / Facility:**

Johnson Space Center (JSC)

**Responsible Program:**

Human Spaceflight Capabilities

### Project Management

**Program Director:**

David K Baumann

**Project Manager:**

Barbara J Woolford

**Principal Investigator:**

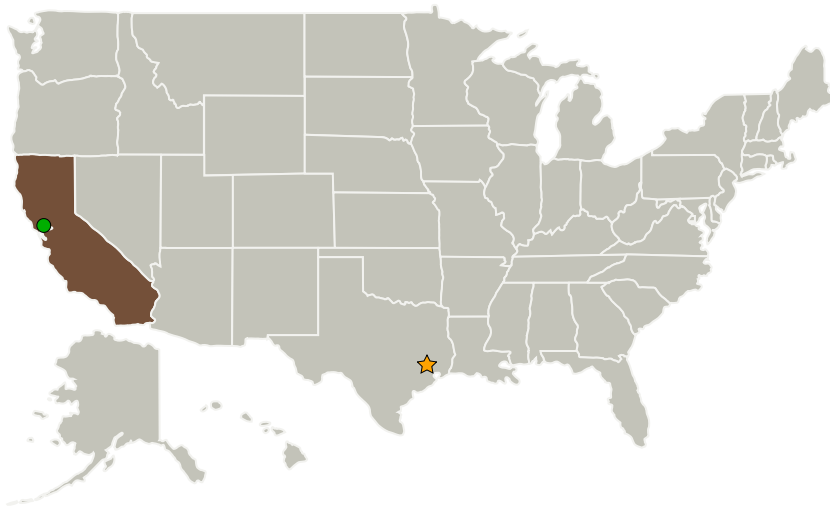
Michael S Feary

**Co-Investigators:**

Lance Sherry  
Collin B Green  
Dorrit O Billman



## Primary U.S. Work Locations and Key Partners



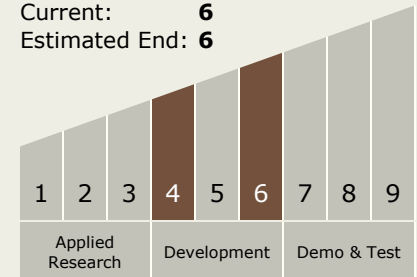
Organizations Performing Work	Role	Type	Location
★ Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
● Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California
San Jose State University	Supporting Organization	Academia	San Jose, California
San Jose State University Research Foundation	Supporting Organization	Academia	San Jose, California

### Primary U.S. Work Locations

California

## Technology Maturity (TRL)

Start: 4  
Current: 6  
Estimated End: 6



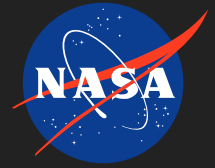
## Technology Areas

### Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - TX06.6 Human Systems Integration
    - TX06.6.1 Human Factors Engineering

## Target Destinations

The Moon, Mars



## Project Transitions

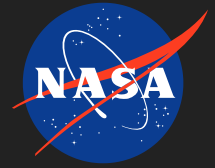
 **October 2006:** Project Start

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 **September 2010:** Closed out

**Closeout Summary:** Our research makes its contributions at two levels. At one level, we addressed the problems of interaction between humans and computers/automation in a particular application domain. The domain of application was the planning work done by Attitude Determination and Control Officers (ADCO), part of Mission Control for the International Space Station (ISS). At a second, higher level, we abstracted from this case to suggest a more general method for needs analysis and this was the primary motivation for our research. We briefly summarize work on the ADCO domain, before describing our more general contribution, the methods and tools that emerged from working on this case. A core aspect of our research was a detailed study of the planning work done by ADCO and identification of the work needs that should be supported by software. As we carried out the analysis of the ADCO planning domain, we changed our characterization of the problem. We realized that rather than focusing on the current tasks and practices, as in Task Analysis, we should try to directly identify their needs, which future software should meet. One result of our work was support for ADCO. We provided an analysis of ADCO needs. We guided development of an illustrative prototype designed to better fit these needs. We conducted an experimental study of this prototype, comparing performance to that with the legacy system. These products are of value to ADCO operators seeking the design of software that is more effective than their current legacy systems. The second, more general result was development of methods and tools for carrying out such analyses. We used the ADCO domain to develop Structure Identification, our approach to needs analysis. We developed Structure Identification to be particularly appropriate for rapid identification of needs for safety critical, technical, information work. Needs analysis based on Structure Identification finds the high-level structure in the work domain and uses this to design the structure of the interaction between the human and computer or automation. We rely on a combination of eliciting function information from expert users, identifying candidate structure from documents and functional descriptions, and vetting the developing characterization with experts. Structure Identification contrasts with conducting needs analysis based on Task Analysis; task analysis identifies current tasks, yet a change in the work applications naturally brings with it change in the tasks so that matching the old tasks is not a reliable design guide. Task Analysis can be a helpful approach to identifying structure, but we prioritize identifying the domain structure not the activities. Our approach is related to both Work Domain Analysis (WDA) and Contextual Inquiry (CI), in that these also seek to identify stable aspects of work in order to guide design. WDA focuses on identifying constraints, particularly constraints in how a physical system, such as a chemical plant, operates; it is directly applicable to control tasks, but much less applicable to work consisting of finding, transforming, building, and distributing information products. CI methods focus on observing users, typically carrying out office work; this approach is less adequate in highly technical domains where critical aspects of work cannot be understood from watching users. Our goal is to make needs analysis more efficient and effective. To this end the methods that we developed focused on gathering important information quickly. We consolidated what we learned to make the methods easier to reuse and to apply to another case, by building simple tools as we carried out the needs analysis for the ADCO planning domain and developed the SI approach. These include templates for gathering high-level function information from experts, templates for presenting the identified structure to experts for verification, and templates for comparing the contents of multiple product documents. An additional contribution of the research was a preliminary assessment of Structure Identification. Broadly, we investigated whether Structure Identification, followed by Structure Matching from the domain to an application structure, contributes to better design of the application. We conducted an illustrative study using the ADCO planning domain. We used the domain structure we had identified to guide design of an experimental prototype for ADCO planning. We conducted an experiment comparing the experimental prototype, which closely matched the domain structure, versus the legacy system, which matched much more poorly. We included a variety of measures, from speed of performance to conceptual understanding and retention of periods of disuse. We predicted differences in performance on a variety of planning tasks that are detailed analogs of simple ADCO planning tasks: overall faster performance by users of the new, well-matched system compared to that by users of the legacy, poorly-matching system; a particular performance advantage for the new system at points where the legacy system most mismatched domain structure. We found that performance times were cut in half for the new prototype vs legacy system on some tasks, accompanied by much lower error rates as well. Further, we also found the predicted pattern of poor performance at legacy points of mismatch. We ran through the whole design cycle, from needs analysis through evaluation, in the ADCO domain. This process provided an illustrative case showing the feasibility of our approach. The results from our experiment suggest that capturing and matching domain structure may be an efficient, productive way to guide design of interaction between humans and computers/automation for technical information work.



## Stories

Articles in Peer-reviewed Journals  
(<https://techport.nasa.gov/file/53886>)

Articles in Peer-reviewed Journals  
(<https://techport.nasa.gov/file/53887>)

Awards  
(<https://techport.nasa.gov/file/53888>)

Papers from Meeting Proceedings  
(<https://techport.nasa.gov/file/53889>)

Papers from Meeting Proceedings  
(<https://techport.nasa.gov/file/53891>)

Papers from Meeting Proceedings  
(<https://techport.nasa.gov/file/53892>)

Papers from Meeting Proceedings  
(<https://techport.nasa.gov/file/53890>)

## Project Website:

<https://taskbook.nasaprs.com>